November 1991

COMPUTER OPERATIONS

FAA Needs to Implement an Effective Capacity Management Program

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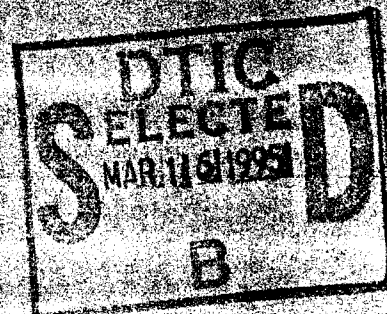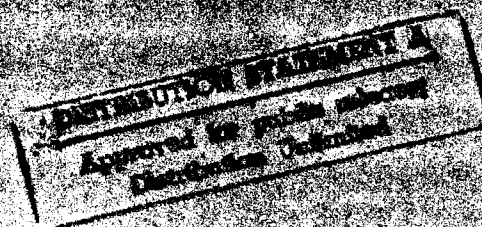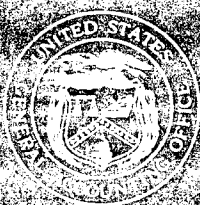
United States
General Accounting Office
Washington, D.C. 20548

Information Management and
Technology Division

B-245307

November 27, 1991

The Honorable Frank R. Lautenberg
Chairman, Subcommittee on Transportation
  and Related Agencies
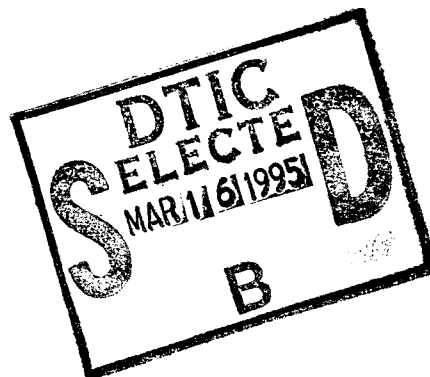Committee on Appropriations
United States Senate

Dear Mr. Chairman:

In response to your request, we are reporting to you on the effectiveness of the Federal
Aviation Administration's management of computer capacity and on how the agency can
improve its practices to alleviate problems with existing systems. Unless you publicly
announce the contents of this report earlier, we plan no further distribution until 30 days
from the date of this letter. At that time, we will send copies to the Secretary of
Transportation; the Administrator, Federal Aviation Administration; the Director, Office of
Management and Budget; interested congressional committees; and other interested parties.
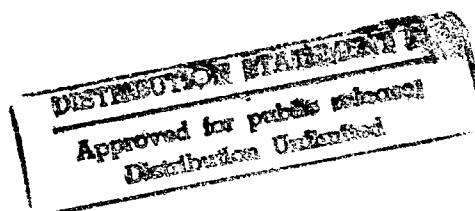We will also make copies available to others upon request.

This work was performed under the direction of JayEtta Z. Hecker, Director, Resources,
Community, and Economic Development Information Systems. Other major contributors are
listed in appendix II.

Sincerely yours,

Ralph V. Carlone
Assistant Comptroller General

Executive Summary

Purpose

To fulfill its key missions of ensuring safe air travel, establishing regulatory standards, maintaining security, and promoting air commerce, the Federal Aviation Administration (FAA) requires a vast amount of information technology resources. Computer resources are especially critical in controlling over 200,000 daily flights across the nation.

Because of his concern about the potential for air traffic control computer systems to continue to experience performance shortfalls, the Chairman, Senate Committee on Appropriations, Subcommittee on Transportation and Related Agencies, asked GAO to report on the effectiveness of FAA's agencywide approach to computer capacity management and on how FAA can improve its practices to alleviate problems with existing systems.

Background

FAA estimates that it spends about $3 billion annually on information technology to support its missions. Much of this is expended on numerous computer systems to promote the safe, orderly, and expeditious flow of civilian and military aircraft. Automated systems at FAA's air route traffic control centers and Terminal Radar Approach Control (TRACON) facilities help controllers maintain aircraft separation. Because these systems are aging, FAA plans to replace them with the Advanced Automation System during the latter part of this decade.

FAA also has 12 "Common System" computer facilities that provide general-purpose data processing for mission and administrative areas, such as aviation safety, and financial, material, and human resources. FAA plans to phase out these computer facilities in 1995, relying instead on computer resources owned and operated by a contractor. FAA's research, engineering, and development program, an important element in improving air traffic control operations and aviation safety and security, is also supported by computer systems.

FAA's tremendous investment in information technology resources requires effective management of computer capacity. Capacity management is the process by which the components of a computerized system are configured, used, and maintained to effectively and efficiently process work loads; it provides the basis for predicting when hardware and software need to be upgraded to meet projected growth.

Over the past 2 years, GAO has issued several reports on FAA's computer capacity management practices.[1] For instance, GAO found that the lack of a computer capacity management program for air traffic control automation systems resulted in computer capacity shortfalls at several facilities, as well as the inability to accurately determine future computer capacity requirements. Further, without a capacity management program, FAA could not determine the cause of performance problems for the Common System computers and was unable to accurately project future capacity requirements.

Results in Brief

Management of computer capacity is critical to FAA's meeting its missions, such as ensuring safe air travel. Although FAA has recently made some limited improvements, it has not implemented a comprehensive capacity management program for its major automated systems because such a program is not a priority. As a result, FAA lacks adequate computer capacity management policies, procedures, expertise, and tools. Without a comprehensive program, FAA does not know how long current systems, such as those used to assist controllers in separating aircraft, will continue to meet capacity requirements, nor does it know its future capacity needs.

Principal Findings

Capacity Management Is Critical to Achieving Mission Success

Capacity management is critical to FAA's mission of providing essential safety and aviation services. For example, capacity management is necessary to correct or prevent processing shortfalls that could hinder controllers' ability to maintain safe separation of aircraft. Capacity management has two key components: (1) performance management, which measures and evaluates system performance to prevent or correct problems; and (2) capacity planning, in which required resources are projected based on estimated work loads and reserve capacity. Federal regulations and related guidance require agencies to conduct capacity management activities. Further, private sector organizations

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[1] Air Traffic Control: Computer Capacity Shortfalls May Impair Flight Safety (GAO/IMTEC-89-63, July 6, 1989); FAA Procurement: Major Data-Processing Contract Should Not Be Awarded (GAO/IMTEC-90-38, May 25, 1990); Air Traffic Control: Smaller Terminal Systems' Capacity Requirements Need to be Defined (GAO/IMTEC-90-50, June 25, 1990); Air Traffic Control: Inadequate Planning Increases Risk of Computer Failures in Los Angeles (GAO/IMTEC-90-49, July 16, 1990).

believe capacity management is an important component of their information resource management activities because it allows them to successfully meet current and future capacity requirements.

FAA Does Not Perform Key Capacity Management Activities

FAA does not have complete capacity management data to support its decisions on operating, upgrading, or replacing systems, resulting in decisions that are sometimes incorrect or untimely. For example, FAA did not take sufficient steps to upgrade terminal air traffic control automation systems until capacity shortfalls occurred, which impaired controllers' ability to maintain safe separation of aircraft. FAA monitors the performance and utilization of some of its systems only periodically or in response to capacity-related problems. Other FAA systems are monitored more consistently, but not in sufficient detail to allow effective problem identification and correction.

Given the previous capacity shortfalls at several air traffic control facilities and continued delays in developing and deploying the Advanced Automation System, accurately predicting future work loads for air traffic control systems is essential. However, except for newly established capacity planning activities concerning the Common System, capacity planning has been almost non-existent at FAA. Although several one-time capacity planning studies were conducted for systems that needed to be upgraded or replaced, planning activities are not performed regularly.

Lack of Policies, Procedures, Expertise, and Tools Hinder Effective Capacity Management

FAA's inconsistent performance management and inadequate capacity planning are due to FAA's failure to make capacity management a priority. As a result, FAA lacks:

- agencywide guidance on computer capacity management for its major automated systems;
- system-specific capacity management procedures for its various air traffic control and administrative systems;
- capacity management positions and expertise to ensure that an effective capacity management program is in place; and
- consistent implementation of automated performance management and capacity planning tools to assist in the collection, analysis, prediction, and modelling of current or future capacity management data.

Recommendations

GAO recommends that the Administrator, FAA:

- Develop computer capacity management policies and procedures for the air traffic control systems and Common System. These policies and procedures should require the implementation of capacity management programs for each type of system and include accepted performance management and capacity planning activities.
- Obtain or develop the additional capacity management expertise necessary to develop policies and procedures and administer capacity management programs.
- Acquire or develop automated performance management and capacity planning tools for each system and consistently implement them to assist in the collection, analysis, and reporting of performance, utilization, and capacity data.

Agency Comments

Department of Transportation and FAA officials acknowledged that capacity management problems exist, but stated that FAA is taking actions to correct them. Officials added that the report needs to more clearly identify differences between real-time air traffic control and general-purpose systems because capacity management activities for these two types of systems vary significantly. FAA officials also stated that capacity shortfalls in air traffic control computers have not caused unsafe separation of aircraft because controllers have other means, such as primary radar information, to ensure that safety is not compromised.

We recognize in the report FAA's actions to improve capacity management. However, because capacity management is a crucial function in helping meet the agency's missions, FAA needs to implement a comprehensive computer capacity management program. Regarding the differences between real-time and general-purpose systems, we acknowledge in our recommendations that specific programs need to be tailored to each type of system. However, the capacity management framework presented in the report is applicable to both types of systems. Finally, while we do not have evidence that capacity shortfalls have actually compromised flight safety, we have previously reported that such shortfalls do impair controllers' ability to maintain separation of aircraft and therefore may impair flight safety.

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Abbreviations

FAA   Federal Aviation Administration
GAO   General Accounting Office
IMTEC   Information Management and Technology Division
TRACON   Terminal Radar Approach Control

Introduction

The Federal Aviation Administration (FAA) is responsible for ensuring safe air travel, establishing regulatory standards, maintaining security, and promoting air commerce. To fulfill these key missions, extensive use of information processing and communications is necessary. Computer and communications resources are especially critical to FAA in controlling over 200,000 daily flights throughout the nation.

Air Traffic Control Automation Systems

FAA's air traffic control mission is to promote the safe, orderly, and expeditious flow of civilian and military aircraft. To accomplish this mission, air traffic controllers communicate weather information, instructions, and clearances to pilots and other personnel; maintain safe distances between aircraft; and guide aircraft departures and approaches. Several computer and communication systems assist air traffic controllers in performing these functions.

To control air traffic that is en route between airports, FAA maintains 20 air route traffic control centers in the continental United States. Each of these centers is supported by an automated system, known as the Host computer system, to help air traffic controllers maintain aircraft separation.

FAA also maintains 182 Terminal Radar Approach Control (TRACON) facilities to sequence and separate aircraft arriving at or departing from airports under its control. The New York facility, which provides air traffic control services for the New York metropolitan airspace, is the busiest TRACON in the country and is supported by a unique system known as the Automated Radar Terminal System IIIE. FAA's 62 other large TRACONs are supported by Automated Radar Terminal System IIIAs, while the 119 smaller TRACONs are supported by Automated Radar Terminal System IIAs.

The Advanced Automation System, the centerpiece of FAA's National Airspace System Modernization plan, is scheduled to replace air route traffic control center and TRACON systems with new hardware, software, and controller workstations. FAA believes that the advanced system, scheduled for initial implementation in the mid to late 1990s, will increase controller productivity, reduce operating costs, save fuel and passenger time, and allow controllers to handle anticipated traffic increases more safely and efficiently. However, as we have previously reported, recent delays in the Advanced System will force FAA to operate

aging computer systems at its air traffic control facilities for several more years.[1]

General-Purpose Data-Processing Systems

FAA's general-purpose data-processing systems, known as the Common System, consist of 23 computers at 12 agency facilities. This system provides support for mission and administrative areas, such as airport and aviation activity (excluding real-time air traffic control); aviation safety; national airspace facilities; and financial, material, and human resources.

FAA maintains that it is no longer possible or desirable to upgrade the Common System to meet the agency's rapidly growing data-processing needs. Therefore, it developed the Computer Resources Nucleus project to replace the Common System. FAA plans to procure data-processing services from a contractor who will be responsible for providing, maintaining, and operating the computer facilities, equipment, system software, and technical support services to meet the agency's general-purpose data-processing needs over the next 10 years. FAA plans to award this contract in early 1992 and anticipates turning the entire Common System over to the contractor by 1995.

Scientific and Engineering Computer Systems

In addition to air traffic control and general-purpose computer systems, FAA supports systems for research, engineering, and technical development programs. Scientific and engineering computers are used by the FAA Technical Center, located at the Atlantic City, New Jersey International Airport, to assist in research projects covering topics such as aircraft separation standards, transport crashworthiness, and aircraft icing. FAA recently decided to phase out these computers and use other available systems. One computer was decommissioned in July 1991, while the other will continue to operate until remaining programs can be transported to either the Computer Resources Nucleus project or other agency computer systems.

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[1] Air Traffic Control: Continuing Delays Anticipated for the Advanced Automation System (GAO/IMTEC-90-63, July 18, 1990); Delays in Critical Air Traffic Control Modernization Projects Require Increased FAA Attention to Existing Systems (GAO/T-IMTEC-91-14, June 14, 1991).

Prior Reports Highlight FAA's Computer Capacity Management Problems

Over the past 2 years, we have issued several reports on FAA's ineffective computer capacity management practices. In 1989, we reported that the lack of a computer capacity management program resulted in computer capacity shortfalls at large, busy TRACON facilities.[2] These shortfalls impaired controllers' ability to maintain safe separation of aircraft. Many facilities reported that they experienced instances of aircraft position and identification information disappearing from controllers' displays, data flickering on displays, and delayed computer responses to controllers' attempts to update or request data. Last year we reported that FAA did not know if its current automation plan for the consolidated Los Angeles basin TRACON facility would meet future needs because the agency lacked a computer capacity management program.[3] We also reported that, for its smaller TRACON facilities, FAA (1) had no assurance that an ongoing system upgrade would meet capacity needs, and (2) could not adequately determine future capacity requirements.[4]

Regarding the Common System, we previously reported that the lack of a capacity management program resulted in insufficient information to determine if response time problems were caused by inadequate capacity.[5] Further, FAA was unable to adequately project future capacity requirements and substantiate its justification for the Computer Resources Nucleus project.

Improvements in FAA's Capacity Management

In response to our previous recommendations, FAA has taken steps to prevent capacity shortfalls from occurring. For example, at large TRACONS, FAA is replacing existing computer memories, which employ outdated technology, with high-speed, solid-state memories and optimizing operational software to improve execution time. The agency also plans to further increase computer capacity by procuring additional processors to expand large TRACON system configurations to their maximum design limits.

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[2] Air Traffic Control: Computer Capacity Shortfalls May Impair Flight Safety (GAO/IMTEC-89-63, July 6, 1989).

[3] Air Traffic Control: Inadequate Planning Increases Risk of Computer Failures in Los Angeles (GAO/IMTEC-90-49, July 16, 1990).

[4] Air Traffic Control: Smaller Terminal Systems' Capacity Requirements Need to be Defined (GAO/IMTEC-90-50, June 25, 1990).

[5] FAA Procurement: Major Data-Processing Contract Should Not Be Awarded (GAO/IMTEC-90-38, May 25, 1990).

To better manage computer capacity, FAA has initiated some limited activities, such as routinely capturing data on system work load (e.g., number of tracks, number of targets), processor utilization, and memory utilization of its large TRACON systems. Additionally, FAA plans to award a contract later this year for the development of an integrated performance monitoring analysis system designed to improve the collection, analysis, and reporting of air traffic control performance and capacity data. FAA officials added that this contract and related activities will represent the foundation of its future capacity planning activities for air traffic control systems.

Objective, Scope, and Methodology

Our objective was to determine the effectiveness of the agency's approach to computer capacity management and identify how FAA can improve its practices to alleviate problems with existing systems.

To accomplish our objective, we reviewed federal regulations and identified criteria for computer capacity management programs. Because these regulations did not provide detailed capacity management criteria, we used additional federal guidance to augment the regulations. To further expand upon this criteria and obtain a broader perspective on capacity management principles and practices, we reviewed industry publications, reports, and conference proceedings. We also interviewed officials, analyzed capacity management reports and studies, and identified effective capacity management practices from several private sector organizations recognized for implementing effective capacity management programs. We selected these private concerns based on our review of industry publications and on recommendations from industry experts.

On the basis of the criteria we identified and synthesized, we assessed FAA's capacity management practices. We selected seven systems for review, covering both air traffic control and general-purpose systems, on the basis of previous reports citing computer capacity management problems. In reviewing these systems, we analyzed agency and contractor capacity plans, studies, reports, and written guidance describing existing and planned capacity management practices. We interviewed FAA officials to determine existing capacity management practices and compliance with federal guidance and accepted computer capacity management practices.

In addition, we evaluated agencywide capacity management policy, and discussed performance management and capacity planning activities

with FAA officials from headquarters, regional offices and centers, and air traffic control facilities. We selected these locations because they either (1) maintained a large amount of the agency's computer resources, (2) had computer systems representative of other comparable facilities, or (3) contained agency-unique computer processing characteristics. We also updated our prior work on FAA capacity management and identified the agency's actions in response to our recommendations. In addition, we identified reasons for discrepancies between FAA's capacity management activities and our criteria.

We performed our work at FAA headquarters in Washington, D.C.; the FAA Technical Center at the Atlantic City, New Jersey International Airport; the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma; FAA regional offices in Jamaica, New York; Kansas City, Missouri; and Atlanta, Georgia; TRACON facilities in Pensacola, Florida; Tampa, Florida; Atlanta, Georgia; Philadelphia, Pennsylvania; and Westbury, New York; and air route traffic control centers in Miami, Florida; Hampton, Georgia; Nashua, New Hampshire; and Ronkonkoma, New York. We also conducted work at Farmland Industries, Inc. in Kansas City, Missouri; MCI Corporation in Arlington, Virginia; and Yellow Freight Systems in Overland Park, Kansas.

Our review was performed between August 1990 and October 1991, in accordance with generally accepted government auditing standards. The views of FAA officials were obtained on the key facts, conclusions, and recommendations contained in this report. Their views are incorporated throughout the report as appropriate. In addition, we obtained oral comments from Department of Transportation and FAA officials on a draft of this report. These comments and our analysis are also included in the report.

Capacity Management Is a Critical Activity

Computer capacity management at FAA is critical to the safe and efficient use of the nation's airspace. Capacity management is the process by which the components of a computerized system are configured, utilized, and maintained to effectively and efficiently process work loads. Additionally, it provides the analytical basis for predicting when hardware and software configurations will need to be upgraded to meet projected work-load growth. The Federal Information Resources Management Regulation and related guidance require government agencies to conduct capacity management activities in planning, acquiring, and using computer resources. Capacity management has two key components: (1) performance management, dedicated to measuring and evaluating current utilization of computer resources; and (2) capacity planning, dedicated to determining what additional capacity is needed to support future missions and ensuring that it is available when needed. Private sector organizations consider capacity management activities to be high-priority company programs and stress their criticality to business success.

Performance Management Necessary to Meet Current Needs

Performance management enables an agency to provide the best possible service to users on the existing system. Federal guidance emphasizes the need for performance management to ensure that services are provided efficiently and effectively. Key performance management activities include: (1) establishing performance objectives, (2) measuring overall system performance and individual component utilization, and (3) analyzing and reporting performance data.

Establishing performance objectives involves defining acceptable levels of service for system users. Levels of service are expressed in terms such as response time, job completion or turnaround time, availability and reliability of computer equipment and services, cost of operation, and accuracy and quality of output. Organizations should formalize their performance objectives by establishing service-level agreements between system users and system providers. Through service-level agreements, users precisely state their system performance expectations, system providers formally commit to satisfy these expectations, and both parties agree on the approach to measure, report, and evaluate performance. These agreements should be updated periodically to ensure current objectives are being met.

Once the performance objectives have been defined, performance and utilization data should be collected. Such performance measurement should focus on both the system as a whole as well as the individual

system components. The components of a system include the central processor, memory, input/output channels, peripheral devices, communications processors, and the associated software and data files. Because system components have different operating characteristics (e.g., size and speed), and because the demand upon these components varies with the work load, poor performance management can result in bottlenecks that degrade overall system performance. At a minimum, performance and utilization data should be collected for the central processor, memory, and channels. This data can be gathered by system facilities, hardware monitors, and software monitors.

After performance and utilization data are gathered, they should be analyzed to determine whether desired performance objectives are being achieved, to isolate the causes of problems, and then recommend adjustments. These adjustments may include changing operational procedures (e.g., processing certain work loads at different times of the day), augmenting hardware, and making changes to operating system parameters. Further, performance and utilization data should be retained for later analysis to ascertain trends or determine the impact of significant events, such as the introduction of new applications.

Capacity Planning Essential for Meeting Future Processing Requirements

Performance management data provides a baseline to predict future resource needs through capacity planning. Capacity planning is the process of predicting future work loads and determining what system resources will be needed to process them effectively. Capacity planning also provides analytical data to support the procurement of system additions and enhancements. The capacity planning process includes (1) projecting future work loads and required user service levels, (2) proposing resources to meet these demands, and (3) planning to obtain the required resources.

Projecting future work loads and service levels requires understanding the current work load and determining what changes are likely to occur. For example, the use of certain applications may increase at some predicted rate, while use of other applications may decrease or disappear. Further, new applications may be implemented on a given schedule and user service-level expectations may change as technology changes. It is generally more difficult to accurately predict long-term work-load changes (5 to 10 years) than short-term work-load changes (less than 1 year).

Once future work loads and user service-level projections are determined, systems that will satisfy these requirements can be proposed. Several methods, including modelling and pilot testing, can be used to define and evaluate alternative system configurations that will process the future work load effectively. Once the best alternative is identified, plans for obtaining the required system resources on a specified schedule are needed. Capacity plans help agencies ensure that equipment is available to meet actual need, thereby preventing processing and capacity shortfalls. Capacity plans should be reviewed and updated at least annually.

Private Sector Organizations Cite Necessity of Computer Capacity Management Programs

Private sector organizations operate in an intensely competitive business environment where the efficient and effective use of information resources is essential to success. Private organizations we surveyed agree that capacity management is a critical component of their information resource management activities. Such organizations have developed and implemented comprehensive capacity management programs that allow them to successfully meet current and future capacity requirements.

At Farmland Industries, an agricultural cooperative, capacity management practices include establishing performance objectives between system users and data processing personnel. Farmland's capacity management team regularly monitors system performance and produces weekly and monthly performance reports that include central processor utilization, disk capacity, and response time. These performance reports are reviewed by system managers to assist in their system capacity assessments. In addition, system users are interviewed periodically to update work-load projections.

Covia Corporation, an airline reservation company, also employs a formal approach for managing its computer capacity. An important element of Covia's program is the construction of capacity planning reports that support its overall strategic planning process. According to a Covia capacity planner, the firm's rapid growth in the industry during the past 2 decades was made possible by the expansion of its data processing capabilities. He stated that Covia's computer capacity management program directly contributed to its business success.

In a similar fashion, MCI Corporation, a telecommunications organization, has successfully employed capacity management programs for

both its administrative data processing and telephone network operations. In particular, MCI uses numerous software tools to help collect system performance and capacity data. Company managers indicated that when conducting performance measurement and data analysis activities, approximately 10 percent of the time is spent collecting data, and up to 90 percent of time is devoted to data analysis. This has improved MCI's ability to correct capacity problems and avoid predicted problems, according to an MCI capacity specialist.

Overall, several private sector firms have found that their investment in capacity management has allowed them to compete successfully today while planning better for the future. They recognize that capacity management is pivotal to meeting their business goals. Appendix I provides additional details on several private firms and their capacity management programs.

FAA's Computer Capacity Management Practices Are Inadequate

Although FAA has recently improved its capacity management practices in some areas, it has not implemented effective computer capacity management practices for most of its automated systems. Specifically, performance objectives for many systems are not current, measurement of system performance is inconsistent, and the analysis and reporting of this data are limited. In addition, future work loads are not projected, additional resources are not proposed, and capacity plans are not prepared for many systems. As a result, FAA does not know how well its systems are performing, when it can anticipate capacity and performance-related problems, or how it will address these problems.

Performance Management Efforts Are Insufficient

FAA's performance management activities for each of its automated systems need improvement. Performance objectives for several automated systems have been established, but some have not been kept up to date. Further, some FAA systems are monitored only periodically or after a capacity-related problem occurs, and the type and amount of performance and utilization data collected and reported varies. The following table summarizes FAA's compliance with the performance management criteria presented in chapter 2 for each of the agency's major systems.

Figure 3.1: Compliance With Performance Management Criteria

	Performance Management Activites		
	Establishing Performance Objectives	**Measuring Performance and Resource Utilization**	**Analyzing and Reporting Data**
Air Traffic Control Systems			
Air Route Traffic Control Center	◓	◓	◓
New York TRACON	◓	◓	◓
Large TRACONs	◓	◓	◓
Small TRACONs	◓	◓	○
Common System			
Aeronautical Center	◓	●	●
Regions	◓	◓	◓
Scientific and Engineering System			
Technical Center	○	◓	◓

● Activity fully complies with federal guidance and accepted industry practices.

◓ Activity partially complies with federal guidance and accepted industry practices—at least one element is performed.

○ Activity does not comply with federal guidance and accepted industry practices.

Performance Objectives Not Maintained

None of FAA's seven systems fully complied with federal guidelines and accepted practices for establishing current performance objectives. FAA established performance objectives, such as response time requirements, for some of its automated systems, but did not always update them. In one instance, FAA never established performance objectives.

Although an important component of establishing performance objectives is formulating service-level agreements, FAA only established service-level agreements with system users of the Aeronautical Center system. In this case, FAA initiated service-level agreements in 1985 on system performance, but has not updated them since then. System performance is now managed on an ad hoc basis as problems arise; user organizations notify FAA Data Services Division staff after they experience performance problems.

Performance and Utilization Not Consistently Measured

Federal guidance and industry practices indicate that at a minimum, performance and utilization data should be routinely collected for such components as central processors, memory, and input/output subsystems. However, FAA does not consistently collect all of this required data for any system, except the Common System at the Aeronautical Center. For this system, numerous performance management tools allow the routine collection of performance and resource utilization data. Data collected include the number of jobs, central processor utilization, average execution time, and average printing time.

While Common System performance data are routinely collected at the Aeronautical Center, they are infrequently collected at regions. Other than a one-time, limited FAA assessment in May 1991 to evaluate system performance and possible system upgrades, each region monitors its system sporadically and does not consistently collect comprehensive data. For example, at some regions, central processor utilization and disk space data are collected, but only when problems are expected or have occurred; at other regions, disk utilization data are routinely collected, but processor utilization and memory data are compiled only on an ad hoc basis.

Data collection for the air route traffic control center computer systems is inconsistent. While data are routinely collected on processor utilization and the number of flight plans being processed, disk and memory utilization data are not collected or analyzed regularly. Without this data, FAA does not know if disk capacity and memory utilization are

nearing maximum limits, thereby posing a threat to continued effective system performance.

Data Analysis and Reporting Infrequent

FAA does not collect comprehensive data on its systems' performance and utilization. Further, it does not thoroughly analyze the data it does collect. For example, data collected on system performance for large TRACON systems are sent to the Technical Center and headquarters, but only a cursory analysis is performed. For the air route traffic control center computer system, a wide variety of data are collected, but only a portion are analyzed. For example, FAA analyzes data on processor utilization, but does not analyze disk capacity or response time data.

By contrast, FAA has analyzed and reported performance data for the Common System at the Aeronautical Center every month since 1979. Reports containing system performance data from the past 4 months are presented monthly to Aeronautical Center officials. The reported data are subsequently analyzed at monthly meetings where problems are identified and solutions are proposed, such as modifying hardware and software to enhance performance.

Capacity Planning Process Is Inadequate

Except for the recent capacity planning activities accompanying the Computer Resources Nucleus project, capacity planning has been almost nonexistent at FAA. Several one-time studies were conducted for systems that needed to be upgraded or replaced, but FAA does not regularly perform planning activities. The following table summarizes FAA's compliance with the capacity planning criteria presented in chapter 2.

Figure 3.2: Compliance With Capacity Planning Criteria

	Capacity Planning Activites		
	Projecting Future Work Loads	Proposing Resources	Preparing Capacity Plans
Air Traffic Control Systems			
Air Route Traffic Control Center	○	○	○
New York TRACON	◖	◖	○
Large TRACONs	◖	◖	○
Small TRACONs	◖	◖	○
Common System			
Aeronautical Center	●	●	◖
Regions	○	○	○
Scientific and Engineering System			
Technical Center	○	○	○

● Activity fully complies with federal guidance and accepted industry practices.

◖ Activity partially complies with federal guidance and accepted industry practices—at least one element is performed.

○ Activity does not comply with federal guidance and accepted industry practices.

Future Work Loads Not Adequately Projected

Most FAA systems do not comply with federal guidelines and accepted industry practices for projecting future work loads. Overall, FAA does not adequately identify when new or modified applications will be implemented, collect work-load projection data from users, or identify projected modifications to performance requirements.

Future work-load projections for the Common System at the Aeronautical Center were last prepared in 1988, based upon information from the Information Resources Management Plan, project managers, users, systems analysts, and historical data. Although this information provided useful work-load projections, it has not been updated since. Further, FAA has not projected Common System work loads at the regions except for the analysis to determine future processing requirements for the Computer Resources Nucleus project.

FAA has performed only minimal work-load projections for other systems. For its air traffic control systems, FAA's projections of future work loads have been based on limited data. For example, processor utilization and system work loads were not adequately projected in determining system alternatives for expanding certain large terminal automation systems. FAA headquarters personnel indicated they asked

Technical Center personnel for future capacity requirements, but the Technical Center staff did not know how to project these requirements at that time. As a result, the computer memory and utilization projections in the study are based on rough estimates from site personnel. Recognizing that it needs to improve in this area, FAA is planning to award a contract later this year to better document work-load trends and predict future performance.

Future Resources Not Always Proposed

Only the Common System at the Aeronautical Center complied with all guidance and accepted practices for proposing future resources. For its other systems, FAA did not identify the resources required to meet expected demand, determine a schedule for updating capacity at all sites, or study alternatives for meeting future resource demands.

For example, large terminal automation systems are undergoing an interim upgrade to sustain operations until they are replaced by the Advanced System in the late 1990s. However, only the busiest locations are currently being considered, and future system work-load requirements are not based on thorough analysis. As a result, it is uncertain how well the interim upgrade will meet FAA needs.

Additionally, future resources for most FAA systems are often proposed after a capacity problem has already occurred. For example, the scientific and engineering system at the Technical Center lacked sufficient capacity to meet users' needs for several years prior to an FAA decision to provide additional capacity through the use of existing or planned computer resources at the Aeronautical Center. Future resources need to be proposed early enough to ensure that service is not degraded prior to the arrival of the future resources.

Capacity Plans Not Prepared

FAA does not have current, complete capacity plans for any of its systems. Some planning was done for the Common System in preparation for the Computer Resources Nucleus project. However, FAA has not developed strategic, long-term capacity plans for all sites, reviewed and updated these plans, or developed tactical or short-term capacity plans for any of its systems other than the Common System.

A strategic, long-term capacity plan was prepared for the Common System at the Aeronautical Center in 1986 and updated in 1988. However, the plan has not been updated since that time. While the Computer

Resources Nucleus project will eventually replace this system, FAA officials indicated that the Common System may have to operate at least until 1995.

In 1986, FAA began developing site-specific capacity plans for the air route traffic control center computer system. These capacity plans were designed to help ensure that the system had adequate capacity at each site for future air traffic work loads, operating environment changes, and software enhancements. However, FAA did not implement site-specific capacity plans. According to an FAA official, the air route traffic control center system had just been upgraded at that time and managing capacity was not a priority for that system.

FAA also did not develop a capacity plan for the scientific and engineering system at the Technical Center. As a result, insufficient processing capacity has degraded system performance and restricted the number of users the system can accommodate.

Lack of Policies, Procedures, Expertise, and Tools Hinder Effective Capacity Management

FAA's failure to implement effective performance management and capacity planning activities agencywide has occurred because the agency has not recognized the importance of capacity management as a priority activity. As a result, FAA organizations responsible for capacity management of the agency's automated systems have not provided sufficient guidance on how to implement effective capacity management practices. Further, sufficient expertise is not available to perform capacity management activities. Finally, the availability and application of automated capacity management tools is not consistent across FAA.

FAA Has Not Implemented Effective Capacity Management Policies and Procedures

The Associate Administrator for Administration and his Office of Management Systems are responsible for agencywide information resource oversight and policy-making activities. At the same time, FAA program organizations retain direct management responsibility for their individual systems. For example, the Aeronautical Center and regions are responsible for managing the Common System, while Technical Center officials are responsible for the scientific and engineering system. The Air Traffic, Airway Facilities, National Airspace System Development, and System Engineering and Development divisions are responsible for managing air traffic control automation systems.

None of these organizations have implemented effective capacity management policies and procedures. FAA's Office of Management Systems has not developed or disseminated any capacity management guidance to program organizations because the office is only responsible for system oversight, while each program organization is responsible for management of its system, according to that Office's Information Resources Management Division Manager. Responsible program divisions have produced some capacity management-related studies, notices, and memos over the past several years. However, in most cases these were generated in reaction to capacity problems and did not comprehensively describe how to implement performance management and capacity planning activities. For example, an Aeronautical Center standards manual discusses performance management reporting for the Common System, but no capacity planning procedures are discussed. Without comprehensive policies and procedures, capacity management practices are either inconsistent or not performed at all.

In one instance, FAA did develop detailed capacity management policies and procedures, but they were never implemented. A capacity management plan was published in June 1986 for FAA's air route traffic control center computer system. A more detailed document defining specific

computer capacity management procedures was later completed in February 1988. These documents described sound capacity management policies and procedures that would ensure that capacity and response time requirements were satisfied over the life of the system. However, according to FAA officials, because no capacity problems at air route traffic control centers occurred at that time, the program was not a priority and was never implemented. As a result, only a small portion of the performance data identified in the plan is currently measured and analyzed. For example, disk capacity and response time data are not collected and analyzed.

FAA Lacks Capacity Management Expertise

To plan, administer, and evaluate capacity management programs, agencies need to designate personnel who are skilled in performance management and capacity planning techniques; familiar with tools that can collect, analyze, and report data; and knowledgeable about the daily operations of the systems. Private sector organizations have such personnel because they have made the capacity management function a priority and devoted the necessary resources to it.

None of FAA's organizations responsible for capacity management have assigned in-house or contract staff to develop a capacity management program. Further, except for one staff person at the Aeronautical Center, none of FAA's organizations have dedicated staff to carry out computer capacity management activities. For example, at FAA's central region, the staff person assigned to capacity management duties indicated she only spends about 5 percent of her time on capacity management activities since there have not been capacity-related problems.

Without sufficient expertise, the effectiveness of capacity management activities is limited. For example, the analyst assigned to capacity management at the Aeronautical Center stated that performance tools cannot be fully used because staff are not available to operate them. This is supported by a consultant hired by FAA, who concluded that the number of capacity management staff in place was inadequate and lacked necessary expertise. In comparison, several private organizations have a significant work force dedicated to capacity management activities (see App. I).

Performance and Planning Tools Are Not Consistently Used

To assist in capacity management activities, performance management and capacity planning tools are often used to collect data. These tools are used to produce reports that help analyze daily activity, project computer capacity, identify system inefficiencies and malfunctions, and improve response time. For example, organizations may employ automated tools to indicate automated resource consumption by a department over a period of time.

The use of these automated tools varies greatly among FAA's automated systems. Some systems are supported by numerous software products that collect, analyze, predict, and model computer performance and planning data, while other systems are not supported by any automated tools. For example, staff maintaining the Common System at the Aeronautical Center have several operating system facilities as well as commercial software products to help them measure computer resource utilization and to determine when capacity will be exhausted. Conversely, performance of FAA's smaller terminal automation systems has not been monitored, although FAA is developing a performance monitor and plans to provide it to smaller TRACONs in 1992.

FAA's use of automated tools is also inconsistent in that different sites operating identical systems do not always use the same performance monitoring tools. For example, staff supporting the administrative system at the Technical Center use two commercial tools to help manage disk storage space, while staff maintaining the same system at the Aeronautical Center are not using any such tools. Because capacity management guidance is not available, there is no method to ensure the consistent use of computer capacity management tools for FAA's administrative computer systems.

Conclusions and Recommendations

Conclusions

A comprehensive computer capacity management program is essential to the successful operation of FAA's major automated systems. Both performance management and capacity planning activities must occur regularly to ensure that computer systems have sufficient capacity to meet both current and future mission needs. Private organizations have discovered that sound capacity management activities are essential to their success in a competitive business environment.

Although FAA has improved some of its capacity management practices, it still has not implemented an effective computer capacity management program for its major automated systems. Without such a program, FAA's capacity management practices are inconsistent and incomplete. Due to inadequate and inconsistent performance monitoring, FAA does not know if its systems are working efficiently and effectively. Similarly, capacity planning for most systems seldom occurs, resulting in uncertainty about when existing systems will need to be replaced or upgraded.

Because capacity management is not a priority at FAA, there is a lack of adequate policies, procedures, expertise, and tools. In one instance where a sound comprehensive capacity management plan was developed for air route traffic control center computers, it was never implemented.

Because the Common System and current air traffic control systems will function for many more years, FAA needs to address these deficiencies. It is especially critical that FAA implement an effective capacity management program for its air traffic control systems, given their crucial role in ensuring aviation safety. Otherwise, FAA will continue to react to serious capacity-related problems after they occur, instead of preventing them before they do.

Recommendations

We recommend that the Administrator, FAA, develop computer capacity management policies and procedures for air traffic control systems and the Common System. These policies and procedures should require implementation of capacity management programs for each system, which include establishing performance objectives, measuring performance and resource utilization, analyzing and reporting capacity management data, projecting future work loads, proposing resources to meet future demands, and preparing capacity plans. In doing this, the Administrator should place highest priority on implementing capacity management programs for systems that are most critical to aviation safety. In

addition, we recommend that the Administrator develop or obtain the capacity management expertise necessary to produce policies and procedures and administer capacity management programs. These personnel should be skilled in performance management and capacity planning techniques, familiar with tools available to collect, analyze, and report data, and knowledgeable about the daily operations of the systems.

Finally, we recommend that the Administrator develop or acquire automated performance management and capacity planning tools for each system and consistently use them to assist in the uniform collection, analysis, and reporting of performance, utilization, and capacity data.

Successful Private Sector Capacity Management Programs

Farmland Industries

This agricultural cooperative, headquartered in Kansas City, Missouri, employs approximately 7,000 and generates over $3 billion in yearly sales. Farmland has six primary areas of business: petroleum products and services, fertilizers, foods, feeds, financial services, and transportation.

Farmland Industries maintains a variety of automated systems ranging from a large, corporate mainframe to a network of microcomputers in field locations. In addition, the company maintains approximately 5,000 remote terminals in 19 states to provide agricultural communities with access to company data bases and information services. The company employs diverse software applications, such as commodity news services; credit cards for gas pump operations; and payroll, accounting, warehousing, and transportation support.

Capacity Management at Farmland Industries

Farmland's current capacity management team consists of a manager, a performance specialist, and a capacity planner. Farmland's managers point out that their capacity management team is a force in the company's management and not simply a reporting mechanism. The team prepares a strategic capacity plan, which serves as an 18-month blueprint for Farmland's automated activities.

Performance Management

In carrying out its performance management activities, Farmland tracks system availability by each subsystem and monitors performance indicators, such as processor utilization, disk paging rates, and response times for users. These various system indicators are used to tune the system and to construct performance reports, which feed into the company's overall strategic capacity plan. Also, Farmland has established service-level objectives in consultation with system users and is currently developing service-level agreements with its customers who purchase information services.

Farmland uses many automated software tools to help collect performance data, which gives managers more time to analyze performance data. In addition, the company has developed data bases to help manage the collected performance data.

Capacity Planning

To prepare capacity plans, Farmland capacity managers use both performance data and work-load projections. To properly project future work loads and new applications, managers measure existing work loads

and interview users to determine future resource requirements. According to a Farmland official, such planning gives Farmland the flexibility it needs to study various ways to meet future capacity demands.

Covia

Covia traces its roots back to the Apollo Services Division of United Airlines. In 1987, Covia became an independent subsidiary of United Airlines. While United Airlines still owns 50 percent of this company, Covia functions as an information service bureau for many travel-related businesses, including seven major airlines.

Although Covia markets a wide range of travel-related products, its major business is airline reservations. Covia's 3,000 employees provide information and reservations to over 15,000 travel agency subscribers in 42 countries through its Apollo System. In addition, the Apollo System makes reservations for 120 hotel chains, 19,000 hotel properties, and 37 rental car companies.

Covia's automated data processing and telecommunications network is composed of a vast array of hardware, software, and telecommunications equipment. Currently, Covia's automated data processing and telecommunications assets include 22 mainframe computers, 65,000 terminals, 30,000 ticket printers, and 2,600 data circuits. The system processes 1,400 entries per second and approximately 6 million airfare changes per day.

Capacity Management at Covia

Covia's information resources require careful management to stay competitive within the information services industry. Thus, the capacity management organization plays an essential role in the company's success. A system performance and capacity planning group is located in each of Covia's three major data-processing areas: host; network; and microcomputer. The host group contains 12 full-time employees dedicated to system monitoring and capacity planning, while the network group has 20 full-time employees dedicated to performance management, capacity planning, and network design. The microcomputer group consists of six full-time employees dedicated to microcomputer capacity planning and local area network performance monitoring.

Performance Management

Covia monitors system performance by tracking daily and monthly performance against stated objectives. The reliability of Covia's host system, for example, is measured in terms of daily system errors and

system availability is measured monthly. Response time is an important performance indicator, and Covia tracks both host response time and network response time, since both affect total users' response times.

Other system parameters measured to track performance against stated goals include central processing utilization, input/output rates, and amount of available storage. Measurements are taken every minute throughout the 24 hours of system operation. In addition, special monitoring is performed for the input/output subsystem. During peak usage, the input/output system is analyzed to track heavily used records and devices. This extensive performance management allows the company to keep each system running as efficiently as possible. According to a Covia official, this results in higher levels of customer service and decreased costs for Covia and its many customers.

Capacity Planning

Covia's capacity planning entails many activities. Covia's work-load forecasting is based on an analysis of historical trends, as well as knowledge of related economic forces such as changes in airline fares. Work loads are analyzed monthly to identify changes, and the company's performance group is required to evaluate the impact of new projects on system performance and capacity.

Covia also constructs 18-month capacity plans for each of its systems. These plans, updated quarterly, include data on projected available capacity, additional hardware needs, and planned major software applications. For Covia's network systems, capacity needs are analyzed and actions are scheduled for each site to accommodate sites' unique requirements.

Yellow Freight Systems Inc. of Delaware

Yellow Freight Systems Inc. of Delaware is a holding company that provides freight transportation services through its subsidiaries. One of the largest freight carriers in North America, Yellow Freight serves more than 300,000 domestic and overseas customers. Its core business is the consolidation, transportation, and redistribution of freight, utilizing a single network of drivers, terminals, and equipment. The company employs approximately 30,000 people located at more than 630 business locations.

Yellow Freight maintains a variety of automated systems. The company recently developed additional computerized services to expand its business base, as well as reduce costs and increase efficiency. The company's new EDI Partners system, for example, can assist customers with shipment tracing, billing, cash management, and planning functions. Another new system—SYSNET—allows the company to obtain information about efficient loading patterns and the most cost-effective routes. Yellow Freight is also replacing its manual data entry operations with a bar coding system to improve quality control and increase the amount of usable management information, and has a pilot project involving mobile, in-cab computers designed to transmit shipment information faster.

Capacity Management at Yellow Freight

Yellow Freight employs a decentralized capacity management approach. Each system group within the company's Management Information Services Division has a capacity management team consisting of a full-time manager and one or two other employees with part-time capacity management duties. Capacity management reports completed by these teams are distributed to directors and vice presidents in the company's Information Services Division. In addition, key personnel regularly review performance management results and upcoming capacity planning issues.

Performance Management

Yellow Freight's capacity management teams collect a variety of computer performance data, including internal response time by transaction, network response time, central processor utilization, processing time by region, and batch time by system. Software packages are used to collect data, build data bases, and analyze systems' data.

Capacity Planning

Performance data and work-load projections are used to construct future hardware and software requirements, which are used to produce a capacity plan. Capacity planning at Yellow Freight considers the impact of (1) expected growth in transaction volume, (2) additional software applications, and (3) enhancements to existing software applications. According to a company representative, this planning process has significantly improved response times for users and prevented the occurrence of sudden capacity problems.

MCI Corporation

MCI Corporation is one of the leading companies in the global telecommunications services market, where change is often dramatic and fast-paced. MCI's 24,500 employees strive to work within this dynamic environment to provide telecommunications services to residential, commercial, and government customers.

Capacity Management at MCI

MCI has a capacity management team for each of its two major information systems divisions. For example, the Data Center Operations Division capacity management team consists of seven full-time employees and a team manager, with the team manager reporting directly to the Vice President for Management Information Systems Operations. The team's primary task is long-term capacity planning.

Performance Management

MCI establishes performance objectives for such indicators as response time, reliability, and system availability. Some of these indicators are recorded and reported daily while others are reported on an exception basis. For example, performance objectives related to MCI's telephone network are reported daily since these are crucial to the business. Like many other successful capacity management programs, MCI uses automated software tools to collect performance data. Currently, software tools collect performance data on the central processor, memory, and the input/output subsystem.

Capacity Planning

MCI measures existing work loads and projects future work loads as part of the company's capacity planning process. Changes in work load are forecasted on a quarterly basis by reviewing historical trends and considering new user-identified software applications. After future work loads have been forecasted, resource requirements are constructed and alternative approaches to meeting these requirements are identified. MCI prepares a 5-year strategic capacity plan, updated annually, which includes a tactical section focusing on the next 2 years.

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